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(71) Applicant *(for all designated States except US)*: DEN NORSKE STATS OLJESELSKAP A.S [NO/NO]; N-4035 Stavanger (NO).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: MURI, Ove [NO/NO]; Ellisivsgate 1, N-4042 Hafrsfjord (NO). PAUROLA, Pentti [NO/NO]; Buseneset 26, N-4046 Hafrsfjord (NO).

(74) Agent: TANDBERGS PATENTKONTOR AS; Boks 7085, N-0306 Oslo (NO).

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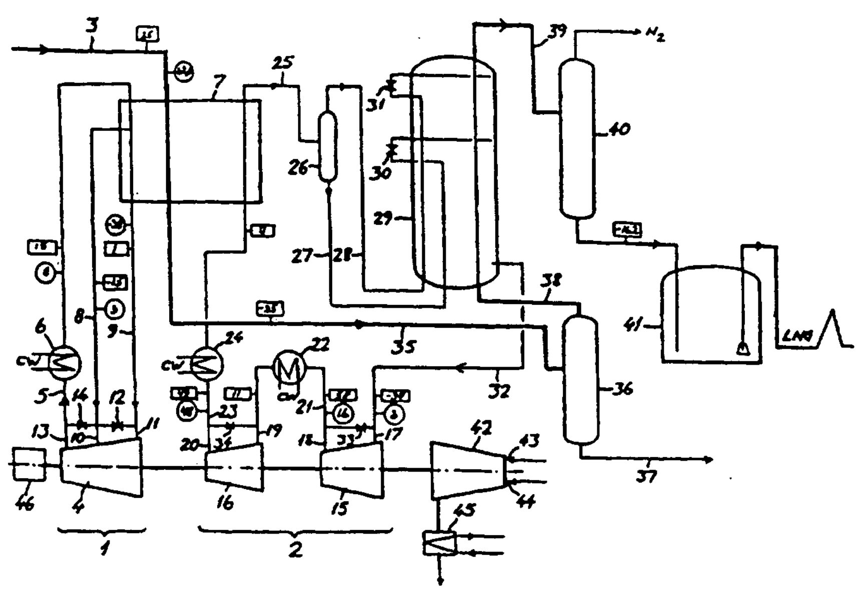
(54) Title: AN INSTALLATION FOR PRODUCING LIQUEFIED NATURAL GAS



(57) Abstract

An installation for producing liquefied natural gas comprises a precooling circuit (1) and a main cooling circuit (2) containing cooling medium for cooling the natural gas, each of the cooling circuits (1, 2) comprising at least one compressor (4 resp. 15, 16) for compressing the cooling medium of the circuit. The compressors (4, 15, 16) in the precooling circuit (1) and the main cooling circuit (2) are mechanically interconnected and are arranged to be driven by a single common gas turbine (42). This is preferably a single shaft turbine having an essentially fixed drive speed during operation, an auxiliary engine (44) being arranged for start-up of the gas turbine (42) and the compressors (4, 15, 16), and for possibly assisting the gas turbine during operation.

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An installation for producing liquefied natural gas

The present invention relates to an installation or plant for producing liquefied natural gas, comprising a precooling circuit and a main cooling circuit containing cooling medium for cooling the natural gas, each of the cooling circuits comprising at least one compressor for compressing the cooling medium of the circuit, and at least one gas turbine for operation of the compressors.

Installations for the production of liquefied natural gas or LNG are extremely capital demanding. Thus, a larger LNG installation will require investments of the order of 1,5 billion US dollars. In addition to the installation cost there come field development, pipeline for landing when it is the question of an offshore field, and dedicated ships for transport of the LNG product. It is therefore very essential to reduce the costs in this connection.

In an LNG installation 30 - 40 % of the building costs lies in the cooling plant proper. The cooling of the natural gas, mainly consisting of methane gas, which is to be cooled down to liquid form, usually takes place in two cooling circuits, more specifically a precooling circuit and a main cooling circuit. Both of these circuits have separate cooling media circulating in closed systems, and which are not mixed with the feed gas, i.e. the natural gas which is to be made liquid. The cooling circuits contain large compressors compressing the cooling media in the respective circuits. During the compression the medium becomes hot. It is cooled down with large quantities of water. Thereafter the medium again expands, and there is generated cold which is transferred to the feed gas. The gas must be cooled to a temperature of -162 °C in order to become liquid at atmosphere pressure.

The precooling circuit usually contains one compressor, whereas the main cooling circuit contains two compressors. These compressors are very large and may have a size of up to 40 000 kW, or somewhat above 50 000 HP. In LNG installations which are built, or which are being built today, there is used either a separate driver for each compressor, or there is used a separate

driver for the compressor in the precooling circuit and a common driver for the two compressors in the main cooling circuit. Because of the large capacity of the compressors, it is usual today to use large gas turbines as drivers. These gas turbines are very expensive, and each single unit needs much expensive supplementary equipment. The installation therefore becomes correspondingly expensive.

The object of the invention is to provide an LNG installation which can be built with substantially reduced costs in relation to the hitherto known installations, and which is also more economic in operation.

The above-mentioned object is achieved with an installation of the introductorily stated type which, according to the invention, is characterized in that the compressors in the precooling circuit and the main cooling circuit are mechanically interconnected and are arranged to be driven by a single common gas turbine.

By means of the above-mentioned solution, which uses only one driver or gas turbine for all the three compressors, there is achieved a number of substantial advantages, such as

- fewer equipment units, also with respect to supplementary equipment,
- fewer pipeline systems,
- a smaller area for the process plant and consequently shorter pipe connections,
- lower cost per unit of power, i.e. a higher efficiency and consequently smaller CO_2 effluence,
- a higher service factor (hours of operation per year),
- smaller investments and lower running expenses.

As a driver in a representative installation according to the invention, which may for example have a capacity of 4 - 5 GSm^3/year, there may suitably be used a gas turbine of the type "General Electric Frame 7" as a common driver, instead of three "Frame 5" gas turbines. Because of the above-mentioned advantages this results in a cost saving of the order of 40 million US dollars. The solution according to the invention may be used both for larger and smaller gas turbines.

The invention will be further described below in connection with an exemplary embodiment with reference to the drawing the only figure of which shows a simplified flow diagram of an LNG installation according to the invention.

The installation shown in the drawing comprises a precooling circuit 1 and a main cooling circuit 2 for the cooling of purified natural gas (feed gas) which is supplied to the installation or plant via a pipeline 3 for treatment in the installation as further described below. The gas for example may be supplied in a quantity of about 490 tons per hour. As appears, the precooling circuit and the main cooling circuit are separate, closed circuits for circulation of respective cooling media. The temperature (in °C) of the cooling media and the feed gas at different places in the system is indicated in the drawing in rectangle symbols, whereas the pressure (in bar a) of the cooling media and the feed gas at different places is indicated in circle symbols.

The precooling circuit 1 in the illustrated case is presupposed to use propane as a cooling medium, whereas the cooling medium may also consist of a mixture of different gases. In the shown embodiment the circuit contains a two-step compressor 4 for compression of the cooling medium. From the compressor 4 a line 5 leads via a heat exchanger 6 to a plate-rib heat exchanger 7, and from this heat exchanger two lines 8, 9 lead back to the compressor 4.

During the compression in the compressor 4 the cooling medium is heated, and it is therefore cooled in the heat exchanger 6 by means of cooling water. In the heat exchanger 7 the medium is expanded and thereby strongly cooled. The medium gives off cold in the heat exchanger and thereby absorbs heat from the feed gas which is supplied via the pipeline 3 and carried through the heat exchanger in separate channels. The feed gas thereby is cooled from about +25 °C to about -35 °C. The heated cooling medium is returned to the compressor 4 via the lines 8, 9 to be compressed again.

As appears from the drawing, at the inlets 10, 11 of the compressor 4 between the lines 8 and 9, there is arranged a bypass valve 12, and between the inlet 10 and the outlet 13 of the compressor there is similarly arranged a bypass valve 14. The

purpose of these valves will be further described later.

The main cooling circuit 2 comprises a low-pressure compressor 15 and a high-pressure compressor 16 for compression of the cooling medium. The low-pressure compressor 15 has an inlet 17 and a outlet 18, whereas the high-pressure compressor 16 has an inlet 19 and an outlet 20. From the outlet 18 of the low-pressure compressor a line 21 leads via a heat exchanger 22 to the inlet 19 of the high-pressure compressor. From the outlet 20 thereof a line 23 leads via a heat exchanger 24 to the plate-rib heat exchanger 7. From this heat exchanger the circuit continues via a line 25 to a separator 26. This has two outlets from which respective lines 27, 28 lead to a main heat exchanger 29 via respective valves 30, 31. From the main heat exchanger a line 32 leads back to the inlet 17 of the low-pressure compressor 15.

The cooling medium in the main cooling circuit consists of an adapted mixture of gases (e.g. methane, ethane and propane) with different boiling points in order to obtain a well distributed heat transfer. After a first compression in the low-pressure compressor 15, the heated medium is cooled in the heat exchanger 22 by means of cooling water (CW). Thereafter the medium is supplied to the plate-rib heat exchanger 7 wherein it is further cooled and thereby is made partly liquid. The mixture of gas and liquid is separated in the separator 26 and is carried further to the main heat exchanger 29 in two flows via the lines 27, 28. After partly cooling in a first part of the main heat exchanger 29 the cooling medium flow is carried via respective ones of the valves 30 and 31 into a second part of the heat exchanger wherein the flows expand and thereby become further strongly cooled. The cooled-down cooling medium flows are sprayed out within the heat exchanger and cause a strong cooling of the feed gas passing the main heat exchanger in separate channels.

In a manner similar to that of the compressor 4 in the precooling circuit, a bypass valve 33 is arranged between the inlet 17 and the outlet 18 of the low-pressure compressor 15. A similar bypass valve 34 is arranged between the inlet 19 and the outlet 20 of the high-pressure compressor 16. The purpose of these valves will be further described later.

In the illustrated installation the compressor in the

precooling circuit for example may be a centrifugal compressor having a power or output of about 21 500 kW. The low-pressure compressor in the main cooling circuit may be an axial compressor having a power of about 38 000 MW, whereas the high-pressure compressor may be a centrifugal compressor having a power of about 27 000 kW.

As regards the feed gas, this is cooled as mentioned in the heat exchanger 7 and is carried further therefrom via a line 35 to a condensate separator 36. In this unit there is separated condensate which is supplied via a line 37 to a condensate storage (not shown). From the condensate separator 36 the feed gas is supplied to the main heat exchanger 29 via a line 38. Because of the strong cooling of the feed gas when this passes the main heat exchanger, it passes into liquid form, but is still under pressure. From the main heat exchanger the feed gas is supplied via a line 39 to a nitrogen separator 40. The feed gas is expanded into the nitrogen separator wherein the nitrogen (N_2) in the gas is separated by evaporation, at the same time as the liquid gas is additionally cooled so that it is in liquid form at atmospheric pressure. The liquid natural gas (LNG) then has a temperature of -162 °C. The liquid gas is supplied to storage tanks 41, in the shown example in a quantity of about 450 tons per hour, in order thereafter to be pumped on board special tankers for transport to the topical destinations.

As appears from the drawing, the above-mentioned compressors 4, 15 and 16 are connected in series and in accordance with the invention are arranged to be driven by a single common driver in the form of a gas turbine 42. The gas turbine is shown to have two inlets 43, 44 for the supply of air and gas, respectively, in operation of the turbine, and an outlet for exhaust gas which is delivered via a unit 45 through which hot oil circulates.

The gas turbine suitably may be a single shaft turbine which produces power firstly at a high drive speed (RPM), and only within a limited drive speed region. It is therefore necessary to use a starter or auxiliary engine 46 to bring the gas turbine up to the necessary drive speed before it can be loaded. In the illustrated example the gas turbine may be of the type "General Electric Frame 7", having a power of 85 000 kW and

a drive speed of 3 600 ± 5 % revolutions per minute. In the illustrated example there is used an electric auxiliary engine of 8 MW having a variable drive speed from 0 to 3 600 revolutions per minute. During normal operation the engine or motor is used as a helper for the gas turbine, in order in this manner to increase the power and thereby increase the production. There may suitably be used an even larger motor (e.g. of 10 MW) to have an extra power on hot days when the gas turbine gives a reduced output.

The entire described unit consisting of the three compressors, the gas turbine and the auxiliary engine, are fixedly interconnected, and in the illustrated example may have a total weight of about 450 tons and a total length of about 45 m. Thus, the whole unit is very large and represents a substantial part of the investment of the installation. It is therefore very important that start-up of the unit takes place in a secure manner. Relief possibilities for the equipment during start-up of the unit are absolutely necessary. If the start-up is not carried out in a proper manner, the load on the motor and the gas turbine may be too large and result in that the entire unit stops during the start-up sequence. This may result in that the motor runs warm, and that damages may be caused on both the motor and the gas turbine.

Start-up of the unit, and the necessary preparations in this connection, will be described below.

The entire fixedly interconnected unit must be brought up to a suitable drive speed by means of the electromotor before air and gas are brought into the combustion chamber of the gas turbine and the turbine achieves the necessary power to get the process started. During the start-up proper therefore all resistance must be reduced to a minimum.

Thus, in order to be able to start up the large equipment unit, the resistance of the cooling circuits must be reduced to a minimum. This is done by opening the bypass valves 12, 14, 33 and 34 of the compressors, and also the valves 30 and 31. One must also take care that other valves (not shown) in the cooling circuits are positioned so as to give the least possible resistance in both circuits. Further, cooling water must be supplied to the heat exchangers 6, 22, 24 having water as a

cooling medium.

The motor 46 is started and sets going the gas turbine and the fixedly connected compressors until the whole unit has come up to a drive speed at which the gas turbine develops a sufficient own power. All valves at the suction side of the compressors are closed. Thereafter the gas turbine is started. When the gas turbine yields a sufficient own power, the valves in the installation are opened, so that feed gas in a limited quantity can be carried through the plate-rib heat exchanger 7 and the main heat exchanger 29. The gas is carried to the flare system of the installation and burnt.

When pressurizing the installation, the precooling circuit is firstly pressurized. The bypass valves 12 and 14 are closed and adjustments of other valves and equipment are carried out, so that the compressed gas is firstly cooled in the heat exchanger 6 and thereafter can expand in the heat exchanger 7 and cool the feed gas.

When the precooling circuit has been made operative, the main cooling circuit can be pressurized. The bypass valves thereof are closed, and thereafter the valves 30 and 31 and other equipment are adjusted in order to achieve the correct pressure drop and expansion of the cooling medium. The cooling medium is cooled in the cooling water heat exchangers 22 and 24 and is additionally cooled in the heat exchanger 7.

When both cooling circuits are operative, the burning of the feed gas via the flare is discontinued, and the feed gas is made liquid. The installation therewith is in operation.

Patent Claims

1. An installation for producing liquefied natural gas, comprising a precooling circuit (1) and a main cooling circuit (2) containing cooling medium for cooling the natural gas, each of the cooling circuits (1, 2) comprising at least one compressor (4 resp. 15, 16) for compressing the cooling medium of the circuit, and at least one gas turbine (42) for operation of the compressors, **CHARACTERIZED IN** that the compressors (4, 15, 16) in the precooling circuit (1) and the main cooling circuit (2) are mechanically interconnected and are arranged to be driven by a single common gas turbine (42).

2. An installation according to claim 1, **CHARACTERIZED IN** that the gas turbine (42) is a single shaft turbine having an essentially fixed drive speed during operation, an auxiliary engine (49) being arranged for start-up of the gas turbine (42) and the compressors (4, 15, 16), and for possibly assisting the gas turbine during operation.

3. An installation according to claim 1 or 2, **CHARACTERIZED IN** that the precooling circuit (1) contains a two-step compressor (4) and the main cooling circuit (2) contains a low-pressure compressor (15) and a high-pressure compressor (16).

4. An installation according to anyone of the claims 1-3, **CHARACTERIZED IN** that, between the inlets (11 resp. 17 resp. 19) and outlets (13 resp. 18 resp. 20) of each compressor (4 resp. 15 resp. 16), there are connected bypass valves (12, 14 resp. 33 resp. 34) which are arranged to be opened during start-up of the installation, to relieve the auxiliary engine (46) and the gas turbine (42) during the start-up.

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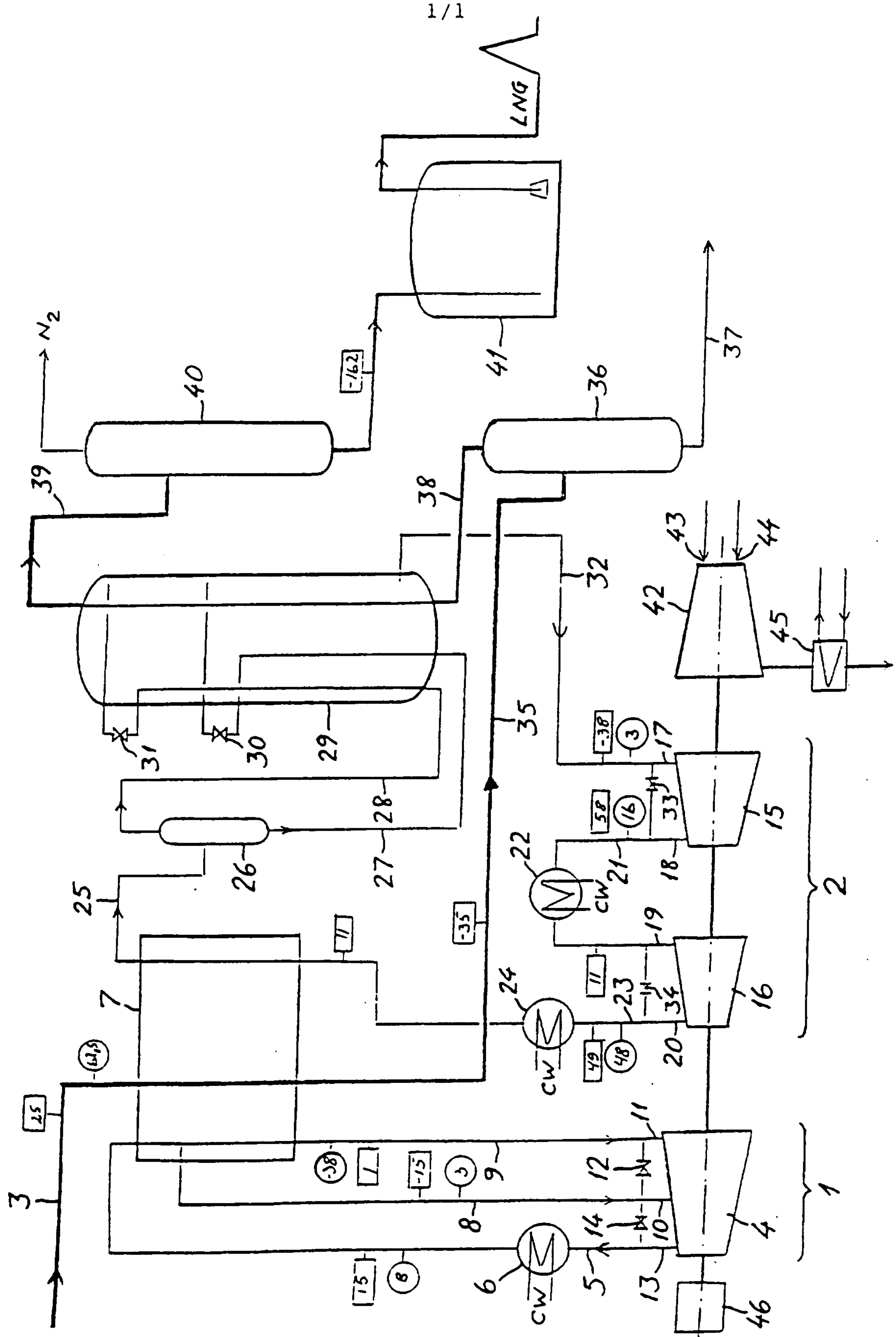

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NO 97/00062

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: F25J 1/02, F25B 11/00
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: F25B, F25J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 3817046 A (AOKI ET AL), 18 June 1974 (18.06.74), column 6, figure 3 --	1
Y	WO 9518345 A1 (INSTITUT FRANCAIS DU PETROLE), 6 July 1995 (06.07.95), Fig. 1 and adherent text --	1-4
Y	GB 1072048ad A. (DOWTY TECHNICAL DEVELOPMENTS LIMITED), 14 June 1967 (14.06.67), page 3, line 44 - line 73, figure 1 --	1
A	US 4566885 A (HAAK), 28 January 1986 (28.01.86), column 2 --	1-4

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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